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EXPERIMENTAL INVESTIGATION INTO EFFECTS OF ADDITION OF ALUMINIUM OXIDE ON PERFORMANCE, COMBUSTION AND EMISSION CHARACTERISTICS OF PONGAMIA BIODIESEL BLENDS IN CI ENGINE

GHANTA RAM SAI AVINASH & VAIBHAV VENKAT

School of Mechanical Engineering (SMEC), Vellore Institute of Technology (VIT), Vellore, Tamil Nadu, India

ABSTRACT

"Effect of Pongamia biodiesel and its blends with aluminium oxide nanoparticle on engine performance, emissions and combustion characteristics in a CRDI system engine (4stroke 4 cylinder) with different engine speed and load has been done here. Diesel, B20, B20A50 dosages were added with an aid of ultra sonicator setup. Maximum torque attained by 15% and 20% POME blends was higher than mineral diesel, while higher biodiesel blends gave a slightly lesser torque. The Alumina oxide gavein1.0%reductioninbrakespecificfuel consumption due to chemical oxidation of fuel, BSFC for lower PME blends was comparable to pure diesel but BSFC increased for higher biodiesel blends. BSCO, BSHC and smoke emissions of pongamia biodiesel blends was lesser as compared to mineral diesel but the Brake specific nitrous emissions were higher. With the average Nitrous Oxide emissions of diesel were 14.09%, 15.46%, than those of B20A50, B20, respectively due to the intrinsic oxygen content in the Pongamia fuel along with better combustion temperature".

KEYWORDS: Pongamia Biodiesel, Aluminium Oxide Nanoparticle, Ultra Sonicator, Performance, Emissions, Combustion & CRDI Diesel Engine

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ABBREVIATIONS

"**B20**80%: diesel blended with 20% biodiesel

B20A50: B20 blend with 50 ppm aluminium oxide nanoparticle

POME: Pongamia oil methyl ester

BSFC: Brake specific fuel consumption

BMEP: Brake mean effective pressure

PME: Pongamia methyl ester

BSCO: Brake specific carbon emission

BSHC: Brake specific hydrocarbon emission

BSNOx: Brake specific nitrogen oxide emission

CRDI: Common rail direct injection

BTE Brake thermal efficiency

HRR Heat release rate

CIME: CallophylumInnophylum methyl ester

SEM: Scanning electron microscopy

TEM: Transmission electron microscopy

FTIR: Fourier transform infrared (spectroscopy)

CAS: Chemical abstracts service

CTAB: Cetyltrimethyl ammonium bromide

HLB: Hydrophilic lipophilic balance

ASTM: American society of testing and materials

ATDC: After top dead centre

RPM: Revolutions per minute

PBD: Pongamia biodiesel

SOI: Start of injection timing

SOC: Start of combustion

ID: Injection delay

CA: Crank angle

ANP: Alumina nanoparticles

POB: Preheated palm oil blends

NaOH: Sodium Hydroxide

Al_2O_3: Aluminium oxide

BTDC: Before top dead centre

C/H: Carbon to hydrogen ratio

BP: Brake power"

1. INTRODUCTION

"The quick consumption of petroleum products and the ascent in transportation expenses has prompted advancement of interchange energizes. Reports from specialists state that the current petroleum product hold will last no longer than 10 years [1]. Also, unsafe vehicular outflows give the need to an elective fuel, which is more secure and ought to be conservative as well. Elective energizes, known as non-regular and propelled fills, are any materials or substances that can be utilized as powers, other than customary powers like, for example, non-renewable energy sources. In the previous couple of years because of across the board increment in the expense and consumption of the petroleum derivatives different research works has been redirected towards finding and investigating the attainability of different substitute energizes and one such alternative fuel is Biodiesel. The main advantage of biodiesel is being

non-toxic, biodegradable and Sulphur free, increases oxygen content which results in better combustion and a change towards the indigenously biodiesel fuels can minimize the expenditure up to a large extent and biodiesels have the advantage that they are nontoxic and inexhaustible in nature [2]. Biodiesels can be extricated from an assortment of normal feedstock sources and comprehensively around 350 yields are perceived as the conceivable feedstock for biodiesel creation [3]. Various sorts of seeds from the plants like pongamia, jatropha, mahua, castor, and so forth are used to create biodiesel which are non-eatable in nature. These non-palatable oil plants are considered as second era feedstock due to their monetarily shoddy and effectively developed in numerous pieces of the world. Pongamia is one such oil that has the advantage that it is a clean and renewable biofuel and has no direct competition with food crops as it is a non-edible source of fuel, andno immediate challenge with existing farmland as it very well may be developed on debased and minor land. Besides, in remote and provincial regions of India, due to non-accessibility of network control, Pongamia oils go about as one of the fundamental hotspots for power age and charge of water system exercises. Pongamia seeds are elliptical in shape and fat pods with size 3–6 cm long and 2-3 cm wide [4]. The reddish brown of pongamia fruit contains 1-2 kernels that exactly look like of the human kidney shape. The pongamia seed kernel is said to have 30%–40% of oil substance and oil can yield 900 to 9000 kg for every hectare. It is one of potential oils with generation of 13500 million tons for every annum except just 6% is being used and is one kind of nonedible oil that can be converted to biodiesel by the process of trans esterification.[5]

However it is broadly acquired as a comparable fuel to diesel working fluid in compression ignition engines, there is an extensive downside in the use of pongamia as higher emissions of NOx and low point heating rate values. With major drawbacks being engine compatibility, cold flow, injector chocking, and high price, various published researches have recorded that problems associated with pongamia can be enhanced by using different set of additives [6]. In a direct or indirect sense, usage of additives can revamp the cutback of exhaust emissions can reduce the nations dependency towards each other by all the means. Additives play a vital role in summiting the international fuel standards proposed with pongamia oil as a working fluid in engine working systems. During the cold flow, usage of additives obstructs the crystalline growth by eliminating the agglomeration with a typical composition of low molecular weight co-polymers producing more compact wax crystals. Though there was no increase in cloud point (CP), there was a recorded lowering of pour point with additives in pongamia through research investigations. Researchers identified that, usage of metallic fuel additives on pongamia has improved its properties as flash point and viscosity values in working conditions prior with fuel characteristics [7]. Additives play a significant role in determining the oxidative stability of pongamia as potential reaction with air in the working medium. Different set of biofuel additives has different rage of effects and advantages to the biodiesel pongamia on meeting real time problems in the operating system conditions. The selection of the additives on pongamia varies with the dependent properties such as solubility, calorific value, viscosity, density, flash point, fire point etc. Based on the property set conditions bio additives such as ethanol, n-butanol, methanol, diethyl ether, additive fuel blends such as B20, B30 etc. and nanoparticle additives such as aluminum oxide, cerium oxide, graphite oxide etc. are generally experimented. Among the above few set of fuel additives, nanoparticle additive in biodiesel has brought an emergent fuel set properties in improving the engine performances and reducing the exhaust emissions. In previous researches, these additives to the biodiesel showed finer thermos physical properties and heat transfer rates ascribed to excessive surface to volume ratio. On exhaust emissions, the nanoparticle additives functions as an oxygen buffer via NOx emission reductions. Aluminum oxide (Alumina) nanoparticle co-solvent has been used as a selective additive to pongamia for the current experimental study. The aluminum oxide was opted as a selective co-solvent for its defined set of properties

over other such as high specific surface area, high defectiveness of the material, high surface concentration, and high degree of orientation. Few research publishers have also recorded some promising outputs with alumina as an additive to biodiesel in the diesel engine operating conditions [8]".

2. LITERATURE VIEW

"Prabakaran et al. [9]Conducted experiments on the dissolvability of ethanol-POME-diesel mixes with the scope of ethanol 20–30%, POME 5–30% and rest diesel in three unique temperatures 5 C, 15, 25 C and the outcomes are contrasted and diesel. BTE decreased by 21% and 9%. BSFC expanded by 39% and 14%. Pressure expanded by 8% and 13%. HRR expanded by 118% and 129%. Examination of Nanoparticle added substances to Biodiesel were accomplished for Improvement of the Performance and Exhaust Emissions in a Compression Ignition Engine. The fuel utilized for the present examination is a biodiesel item rapeseed methyl ester. **Nanthagopal et al. [10]** worked on performance of nanoparticles to biodiesel. The present work targets researching the impact of zinc oxide and titanium dioxide nanoparticles expansion in Calophylluminophyllum biodiesel in twin chamber water cooled direct infusion to a four stroke diesel motor. CIME Nano emulsions containing nanoparticles would be advised to brake warm effectiveness contrasted with unadulterated CIME. Higher brake warm productivity was found for all CIME Nano emulsions when contrasted with all other CIME Nano emulsions and flawless CIME fuel because of the synergist impact of nanoparticles present in the Nano emulsions. **Alok Ranjana et al. [11]**experimented CI engine to keep running on 100% CalophyllumInophyllum methyl ester (CIME) biodiesel and the equivalent snoozed with fuel added substances. ZnO was added to CIME as Nano liquid at various constituent degrees of 50ppm and 10ppm while Ethanox was included at fixation levels of 200ppm and 500ppm. Expansion of ZnO nanoparticle and ETH hostile to oxidant brought about an improvement in brake warm proficiency yet the component by which the improvement is accomplished is diverse if there should be an occurrence of both the additives. **Siva Kumar et al**. [12]investigated the impact of aluminum oxide nanoparticles as added substance to pongamia oil methyl ester (POME). The brake explicit fuel utilization of mix B25A100 fuel is extensively decreased when contrasted with biodiesel mix activity. It is because of the certifiable results of nanoparticles on properties of biodiesel mixed fuel. The brake warm proficiency of nanoparticles mixed biodiesel B25A100 demonstrates a significant improvement when in contrast with that of biodiesel mix and mineral diesel. **Senthur Prabu et al**. [13]conducted examinations of liquor mixing with diesel. The preheated palm oil/diesel mixes (PO20, PO30, and PO40, PO20+BHT and PO20+n-butanol) were effectively utilized as wellspring of fuel in DI diesel motor. The brake explicit fuel utilization of PO20+BHT mix is 11.4% higher than that of diesel while the brake warm effectiveness is 5.1% lower than diesel fuel. Then again the warmth discharge pace of PO20+n-butanol is higher than that of diesel fuel prompts increment in NOx emanation (1.9%), close by the CO outflow is 37.5% lower than diesel fuel on account of lower thickness of n-butanol. **Varatharaju Perumal et al. [14]** conducted experiments on CuO nanoparticles blending with pongamia biodiesel. Poultry litter oil biodiesel was set up with 20% biodiesel and 80% diesel by volume. It was inferred that B20CuO100 mix BSFC had been diminished to a lot of 1.0%, however the BTE had expanded about 4.01%. With nano added substance an expanded BTE had been watched contrasted with diesel at full load. The in-chamber weight was observed to be same for every single working condition. **Anand** [15] performed investigates Emission control technique by including alumina and cerium oxide nano molecule in biodiesel. An exploratory examination is done to think about the exhibition and emanation qualities in a solitary chamber, four stroke diesel motor. It was discovered that there was improvement in brake warm effectiveness and there was a decrease of nitric oxide, carbon monoxide, unburned hydrocarbon and smoke discharge after the expansion of nanoparticles co-solvents **Jabbar Gardy et al.** [16] performed probes Biodiesel generation from utilized

cooking oil utilizing a novel surface titanium oxide Nano-impetus a novel, effective TiO2/PrSO3H strong corrosive Nano-impetus. The synthesized Nano-impetus was portrayed utilizing FTIR, SEM, and TEM. N2 adsorption–desorption isotherms result showed that surface alteration diminished the surface territory of TiO2 NPs by 5% with an expansion in the mean pore size and all out pore volume. The improved synergist execution for the most part identifies with the stacking of propyl sulfonic corrosive gatherings on the outside of TiO2 NPs. **Sarvananet al.** [17] performed probes the impacts of nano metal oxide mixed Mahua biodiesel on CRDI diesel motor. Aluminum oxide nanoparticles (ANPs) were added to Mahua biodiesel mix (MME20) in various extents on a four stroke, single chamber, regular rail direct infusion (CRDI) diesel motor. Results uncovered a generous upgrade in the brake warm effectiveness and a minimal decrease in the destructive toxins, (for example, CO, HC and smoke) for the nanoparticles mixed biodiesel. ANP-mixed biodiesel (MME20 + ANP50 and MME20 + ANP100) demonstrated an improvement in the calorific worth and a decrease in the glimmer point contrasted with MME20".

3. NOVELTY AND OBJECTIVE

With the rise of energy demands decrease of non-renewable energy sources and severe discharge standards encouraged established researchers to scan for interchange fills, for example, biodiesel for diesel motor applications which conquer any hindrance among interest and vitality hotspot for car area. A move towards initially delivered biodiesel energizes decreases the expenses and this can lift up the nation economy. Biodiesels are promptly accessible, bio degradable, compact, nontoxic and sustainable in nature and can be separated from an assortment of characteristic feedstock sources. Biodiesel has couple of downsides, for example, oil thickening at higher temperature, higher outflow and lower execution and left writing holes in past investigations. Thus fuel added substances may play out an essential part in making up the issues and get diverse indicated standards. A nano added substance by and large improves the burning proficiency and diminishes the emission. Recent examinations report that fuel modifications have been actualized by incorporating forthcoming nanoparticles alongside aluminum oxide, cerium oxide, and titanium dioxide in the biodiesel to upgrade fuel and motor traits. Metallic based mixes; for example, manganese, copper rhodium, iron, copper and platinum and so forth have been utilized as burning impetus for hydrocarbon fuel. Late propels in nano innovation brought about generation, control and portrayal of Nano scale vivacious materials. The fundamental reason we use nano molecule is a direct result of its size, the particles are micron estimated so there is no way for stopping up and fuel injector exhibitions on nanoparticle aluminum oxide has not been totally performed in past researches. Nano Additive encourages motor to consume fuel better and the abundance air diminishes the CO content. The temperature inside the chamber during burning diminishes because of the nearness of added substance in the mixed fold and consequently it decreases NOx emanation. Expansion of nano particles with biodiesel upgrades the BSFC and BTE contrasted with diesel fuel. While thinking about outflows NOx, smoke, HC and CO emanations diminished fundamentally however burning has not been obviously revealed at then leaving holes between. It was additionally uncovered that, higher in-chamber weight and warmth discharge was seen with the cerium oxide mixed with Be20. Alumina oxide nano particles induced the combustion characteristics but not as reported in other nano additives. The nano additive was supportive for initiating early combustion and due to this high liberation of heat. Heat release rate for alumina (50ppm) blend with pongamia and pressure data for various load comparing pure diesel, Be20A50, Be20 has a not yet performed in the previous researches on the following engine operating conditions. And so we have covered the following results and information in the following work considering the engine conditions and properties classified with additives and solvents of the biodiesel used.

4. MATERIALS AND METHODS

4.1 Preparation of Pongamia Oil

Pongamia is extracted from the dried seed through esterification process.

4.1.1 Acid Catalyzed Esterification Process

In one cycle of process we used around six litres of pongamia oil. For one litre of pongamia oil we added 300 ml of methanol. The sample mixture is heated at a temperature of 60°C for different time duration (60min, 90min, 120min, and 150min). From these different iterations it was found out that 60°C and 120min was found out to be the most optimum operating condition.

4.1.2 Alkali Catalyzed Trans-Esterification Process

Sodium hydroxide is the alkali catalyst used here. For one litre of pongamia oil 7.5g of NaOH was added. So first we pour the oil in the transesterification tank and after it reaches 60°C we pour the mixture of methanol and NaOH. Since the boiling point of methanol is 60°C we pour it at that particular temperature. We did these various iterations at different time as mentioned above and it was found out that 2 hours gave the most optimum yield. After the time is done, we have collected the glycerine from the tank. By this procedure, biodiesel was created because of response between pongamia oil and a liquor utilizing a solid alkyl impetus (NaOH). In the present investigation, Pongamia biodiesel has been set up in little amount at VIT college research facility. It was evaluated the generation cost of Pongamia biodiesel was approximately 2.3 times higher than oil diesel cost.

4.1.3 Purification of Oil

The resultant product from alkali trans-esterification process consists of ester of Pongamia along with methanol. Water is heated up to 40°C and poured into the biodiesel. After 30 mins the water gets separated from biodiesel and it is then collected. This washing process is done three times. Then the biodiesel is heated up to 100°C. After heating it is later collected. The biodiesel production was done in a small scale and in a 5litre scale. We must make sure that none of the measuring flasks contain any water while pouring biodiesel. The main point to be noted here is the right proportion of methanol and NaOH must added otherwise hard solid mono glycerides would be formed.

4.2 Preparation of Nano Fluids

Table 1

S.no	Parameters	Al_2O_3
1	Manufacturer	Sigma Aldrich
2	Chemical name	Aluminum Oxide
3	Molecular weight	101.96g/mol
4	Average particle size	25nm
5	Form	Crystal
6	Color	White
7	Purity	99.9%
8	CAS number	1344-28-1

In the present investigation, Alumina oxide was utilized with biodiesel as nano emulsion and their consequences for diesel motor. Nano liquid is a fluid which is made out of nanoparticles and refined water. In the present work, the Nano liquid is set up by ultrasonication process. The nanoparticles are scattered in refined water utilizing aultrasonicator with a recurrence of 50–60 kHz for 30 min span. The Nano liquids are set up for two unique convergences of 50 ppm and 100 ppm for the nanoparticles of Al2O3. The got Nano liquid examples are smooth white shading for different cases, for example, Al2O3-50 ppm, Al2O3-50 ppm. The basic properties of nano-particles were listed in Table 1.

4.3 Preparation and Properties of Pongamianano Emulsion

“The Al_2O_3Nano fluids are then blended with Pongamia to form nano emulsion for the present investigation. Four newly emulsified fuels have been developed from the newly prepared Nano fluids which constitutes of 93% of Pongamia, 5% of Nano fluids of Al_2O_3of50 ppm and 100 ppm concentrations and 2% of CTAB (Cetyltrimethyl ammonium bromide) by volume. Due to the small size of nanoparticles, the stability of fuel suspensions should be noticeably improved. These nano particles have high surface to volume ratio so to stabilize them we use surfactants like CTAB (Cetyltrimethyl ammonium bromide). CTAB is a cationic surfactant and forms an envelope on the surface of the particle and makes the surface as negative charge. After this process the surface to volume ratio becomes quite stable. Then after it gets stable nano particles are dispersed with a base fluid like ethanol. Then it is blended with biodiesel blend with the help of ultrasonicator.

CTAB with a HLB estimation of 10 was chosen for emulsified fuel readiness. A mechanical stirrer was utilized for the fuel tests readiness at speed of 1500 rpm under air conditions for 45 min term. The readied pongamianano emulsion energizes were observed to be in caramel shading for each of the four examples. The fuel tests were kept in shut holders for finding their soundness. It was noticed that there was no stage partition in every one of the four fuel tests in these three days. Different properties, for example, kinematic thickness, thickness, lower calorific worth and cetane number were assessed according to ASTM standard test methods and the equivalent has been displayed in Table 2. It has been distinguished that the cetane number of all the pongamianano emulsions were practically identical to unadulterated biodiesel. In addition, the calorific estimations of every one of the four pongamianano emulsions were possibly lower than unadulterated pongamia biodiesel”.

Table 2

Properties	Diesel	B20	B20A50	Accuracy
Density(kg/m^3) @15 °C	810	868.6	873.1	±0.1 kg/m^3
Kinematic viscosity(Cst) @40 °C	2.2	4.72	4.78	±0.35%
Calorific value (MJ/kg)	42.50	37.58	36.02	±0.001 MJ/kg
Flash point	75	122	124	±0.1 °C
Cetane number	45	52	56	±0.1

5. EXPERIMENTAL SETUP

Table 3

Model	TATA
No of cylinder	4
Stroke	Four stroke
Type of cooling	Water cooled
Ignition	Compression ignition
Bore	93.45mm
Stroke	128mm
Compression ratio	18.5:1
Displacement	1670cc
Rated Power	21KW
Static fuel injection timing	24°bTDC
Standard Injection pressure	200 bar

Figure 1

A four-stroke four cylinder TATA model water cooled compression ignition system engine was operated for conducting the combustion, performance and emission characteristic analysis as shown in figure 1. Pongamia biodiesel was used as a fuel here for performing the analysis at engine operating conditions with the help of dynamometer. The engine exhaust emissions such as CO, CO2, and NOx were measured by the AX-409 PEIZO powering unit emission analyser as shown in figure 1.1. The experiments are conducted with diesel, B20, B20A50 using aluminum oxide as a Nano-additive. The technical specifications of engine setup are tabulated in table 3 below. The volume uprooted by the cylinder was 660 cc and the pressure proportion was 17:1. The wrench point at whichthe fuel was infused was 23 degree before TDC. The variety of in-chamber weight regarding wrench point was estimated utilizing AVL GH12D scaled down weight transducer with AVL 3066A02 piezoelectric charge enhancer and edge encoder. Warmth discharge rates from the deliberate estimation of weight and wrench edge was determined and shown utilizing AVL 617 Indimeter programming adaptation V2.00. The wrench edge position to beginning of ignition, event of most extreme pinnacle weight and event of greatest warmth discharge rate were taken from information record produced by the Indimeter programming during the test. Sonication is being made for the fluid

particles to disperse in the liquid medium which is being surrounded using the ultra sound energy. In this experiment, the setup of ultrasonicator i. e. ultrasonic bath was used to fluster the aluminum oxide nanoparticles is the set of blends samples used above in pongamia oil methyl ester with an additive concentration of 50ppm. For the above set of chemical properties shown in table 2, bomb calorimeter was used as a setup for determining the calorific value for the above set of samples made. The kinematic viscosity was set up with the redwood viscometer setup for blend samples.

The above setup was used at the following engine operating conditions for the pongamia biodiesel as a working fluid. Operations were performed one after other in the engine for analysing the characteristic properties.

The emission values are shown in the analyzer as shown below as per the values recorded during experimentation and were being operated in figure 1.1

The production unit experimented then is shown below as per the records measured during the operation.

Figure 1.1

Figure 1.2

6. RESULTS AND DISCUSSIONS

Work aims at finding the effect of different Nano emulsion blends on engine combustion, performance and emission characteristics under various biodiesel blends at 2500 rpm on different loads. Experimentation has been carried out in diesel engine with four different Nano emulsions and the results were compared with diesel and Pongamia biodiesel. The schematic diagram of experimental engine test setup is shown below in figure 1.3 below.

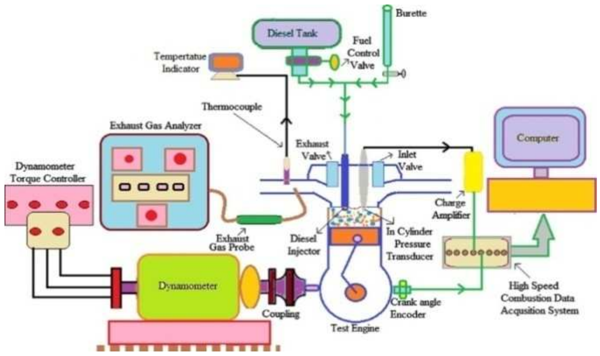

Figure 1.3: Schematic of Experimental Engine Test Setup.

6.1 Emission Characteristics

Various emissions such as hydrocarbons, carbon monoxide and oxides of nitrogen were measured in the diesel engine when fuelled with pure diesel, Nano emulsions of pongamia-B20, pongamia B20A50. The CO, HC and NOx emissions were converted from ppm into g/kW h as per the standard testing procedure.

6.1.1 Brake Specific Hydrocarbon (BSHC) Emission

"The changes in brake specific unburned hydrocarbon emission in respect with the BMEP for pure diesel and Nano emulsionofB20, B20A50 are shown in Figure 2. As per the trend, the unburned hydrocarbon emissions decreased with increase in engine brake power for all tested fuel. HC is emitted due to incomplete combustion of fuel in the combustion chamber. The structure/composition of the fuel, construction of the engine operating conditions is important parameter that affects the HC emissions. Fig.2 shows the change in HC emissions for different test fuels. At high brake mean effective pressures, high HC emission is noticed; this is due to high load operating conditions to maintain the uniform engine speed as the requirement of fuel is more. This results the fuel injecting into the combustion chamber rapidly. The injected fuel cannot be oxidized or is partially oxidized which leads to decreased combustion duration leading to increased HC emission. Furthermore, the high HC emission of PBD fuel, when compared to other test fuels, can be attributed to the higher C/H ratio of PBD. While comparing the HC emissions of Diesel, B20, and B20A50it is found out that B20 emitted more emission more than B20A50. In the case of nanoparticles blended biodiesel fuel, the degree of air-fuel mixing could have improved, due to secondary atomization and improved catalytic effect associated with the dispersion of nanoparticles in the biodiesel fuels".

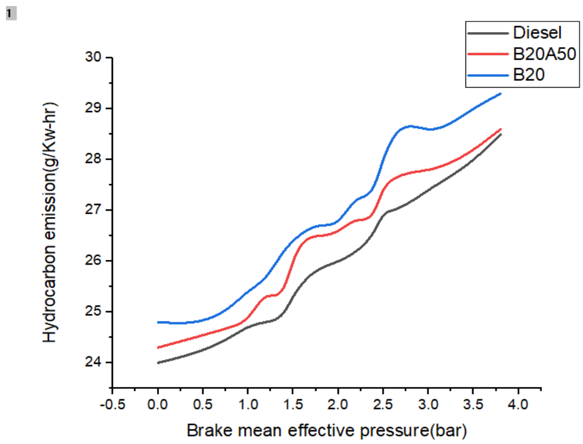

Figure 2: Variation of Hydrocarbon Emission.

6.1.2 NOx Emissions

“Nitric oxide (NO) and nitrogen dioxide (NO2) are usually combined as NOx. Diesel engines release large quantities of oxides of nitrogen than the engines which run on petrol and other fuels. Temperature, oxygen concentration and combustion duration are the critical parameters which affect the NOx formation. Combustion chamber type and shape, compression ratio, injection timing and pressure, the start of combustion and its duration and the physic chemical characteristics of fuel such as viscosity, density and cetane number also influence NOx emissions from internal combustion engines. NOx emissions of the test fuels and their variations with the engine brake mean effective pressure were determined as given in Figure 3 as shown in the figure. NOx emissions show homogenous trends for all test fuels. As the brake mean effective pressure on the engine was increased from 0.0 bar to 4.0 bar, NOx emissions increased. This is because of higher oxygen content coming from, the higher air fuel ratio. The average NOx emissions of diesel were 14.09%, 15.46%, than those of B20A50, B20, respectively. It can be noted that BSNOx emission for the Pongamia fuel was 35% higher than conventional diesel fuel at 100% engine load. The reasons for this behavior are the intrinsic oxygen content in the Pongamia fuel along with higher peak combustion temperature during Pongamia fuel operation. When cetane number is high, it leads to shorter ignition delay. Large cetane number reduces the size of the premixed combustion by reducing the ignition delay, thereby allowing less time for mixing of air-fuel. Moreover, the pongamia biodiesel has unsaturated fatty acid, which will increase the NOx emissions. Higher latent heat of vaporization and lower heat value of test fuels without the addition of additive results in higher volume of fuel injection consequently cylinder charge temperature and combustion temperature fall and NOx emissions shrink”.

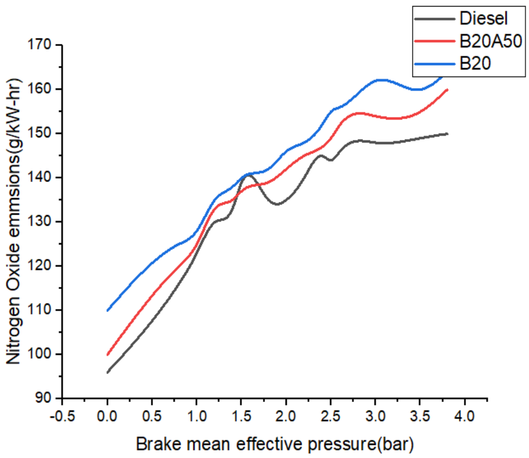

Figure 3: Nitrogen Oxide Emission.

6.1.3 Carbon Monoxide Emission

“Figure 4 shows the variation of carbon monoxide level of blends as compared to diesel with respect to brake mean effective pressure. It is observed that the CO of blends is higher than that of diesel before part BMEP. This is due to the poorer atomization and cooling effect as the ethanol in the blend improves the heat of vaporization as compared to diesel. This reduces the average temperature of the combustion chamber. The CO emission was 24.5% lower for B20A50 fuel operation than that of B20 at100% engine load. However at higher brake mean effective pressures, the dominance of the heat of vaporization reduces and better complete combustion occurred, leading to lesser CO emissions. When Alumina nanoparticle is added emission reduces compared to B20. This is due to addition of nanoparticles, which aids in combustion due to the catalytic action, thereby reducing CO emissions”.

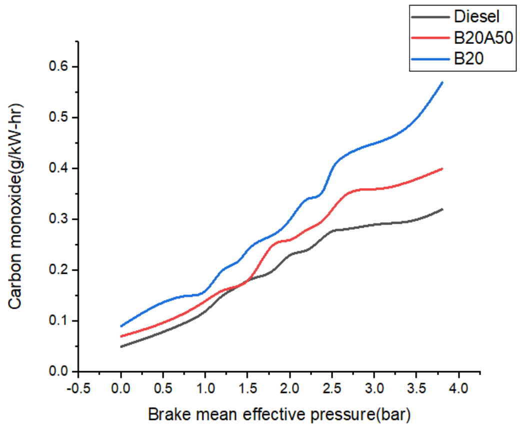

Figure 4: Carbon Monoxide Emission.

6.2 Combustion Characteristics

6.2.1 Cylinder Pressure and Crank Angle

"Cylinder pressure of an engine varies throughout the four-stroke engine cycle. Work is done on the fuel by the piston during compression, and the gases produce energy through the combustion process. The pressure change in the cylinder of an engine affects the start of injection (SOI) timing, ignition delay (ID) and the start of combustion (SOC). Figure 5 shows the changes in the cylinder pressure of the test fuels with variation crank angle (CA) under at full load condition. For combustion analysis, the peak cylinder pressure is correlated with the crank angle. The maximum cylinder pressure of B20A50, B20 were 1.16%, 0.346% more (on average 0.27%) than the Diesel respectively. Biodiesel possesses lower peak cylinder pressure because of the long ignition delay Figure 5 indicates that PBD exhibited a maximum cylinder peak pressure of 93.5 bar at 371°CA after top dead centre (ATDC), whereas the minimum cylinder peak pressure was 5 bar at 320°CA ATDC with the B20 fuel. This is due to the low viscosity of PBD, due to which the flow of fuel will be smoother and result in enhancing the fuel-air ratio and building more cylinder pressure. Moreover, earlier ignition of PBD results in the early start of combustion and hence higher pressure values for PBD was observed".

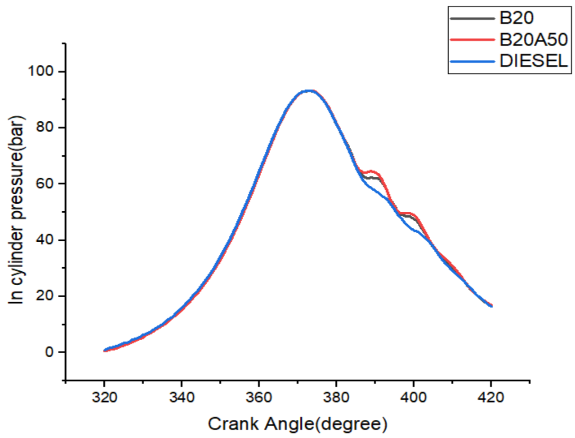

Figure 5: Relationship between Cylinder Pressure and Crank Angle.

6.2.2 Heat Release Rate and Crank Angle

"The heat release rate of test fuels with varying crank angle at full load condition is shown in Figure 6. From the heat release rate plot it is found out that heat release rate slowly increases during the first stage of combustion because of

vaporization of the fuel accumulated during the ignition delay; when combustion is initiated, the heat release rate rapidly becomes positive. From the heat release rate analysis, the peak heat release rate was determined as 92 kJ/°CA with PBD fuel at 360°CA. This may be due to higher volatility of diesel and its ability to mix with air Fig.6 shows that B20 showed a lower peak heat release rate than those of B20A50. Figure 6 shows that the B20 and B20A50 fuels displayed peak heat release rates of 94.2 kJ/°CA and 92.3 kJ/°CA, at 369°CA and 372°CA ATDC respectively; these rates are approximately 17.37% and 18.63% lower, respectively than the that of the PBD fuel. Overall the PBD fuel showed higher heat release rate than other test fuels. These results can be attributed to the low density, low viscosity and high calorific value of the PBD. Finally, this condition causes rapid vaporization of the PBD, thereby contributing to pre-mixed combustion. Another observation from the peak heat release rate plot is that the B20A50 showed less heat release than B20fuel. This trend may also be assigned to the higher density and viscosity of the nano particles blended fuel due to which, the vaporization of fuel is slow showing a negative effect on the heat release rate".

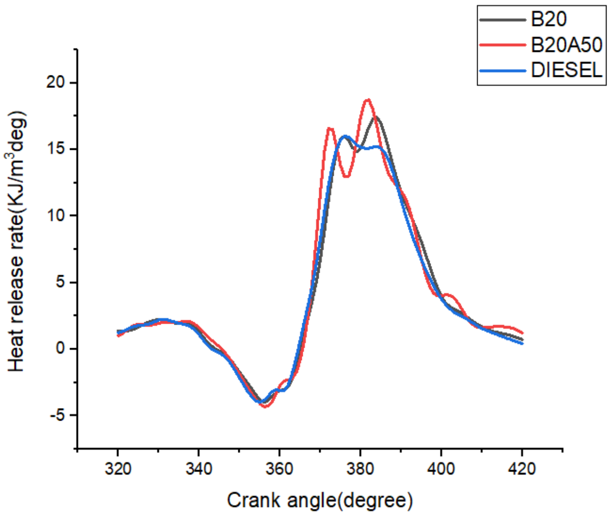

Figure 6: Relationship between Heat Release Rate and Crank Angle

6.3 Performance Characteristics

6.3.1 Brake Specific Fuel Consumption

"The variation of BSFC with respect to BP for the Alumina nanoparticle added PME blends of B20, B20A50 and diesel has been shown in Figure 7. From the figure it was found out that the BSFC for the Alumina blends decreases compare to that of B20. It has been inferred that the pongamia Nano emulsion fuel samples improved the brake specific energy consumption compared to pure biodiesel. The BSFC has been decreasing while the percentage of Nano particles in the fuel blends. The decrease in BSFC was due to the improved physical properties of fuel and the short ignition delay which causes complete combustion [18, 19]. The$Al_2O_3$with biodiesel resulted in 1.0% reduction in brake specific fuel consumption due to the catalytic chemical oxidation of fuel. Alumina nanoparticles in the blend assists the combustion activity by the catalytic action thereby enable better combustion at high temperatures. Also, the surface to volume ratio of nano particle is higher, better atomization of fuel blend happened at high temperatures. The nanoparticles acts as oxygen booster and hence the complete combustion occurs. Due to this the fuel consumption decreases compared to pure biodiesel [20]".

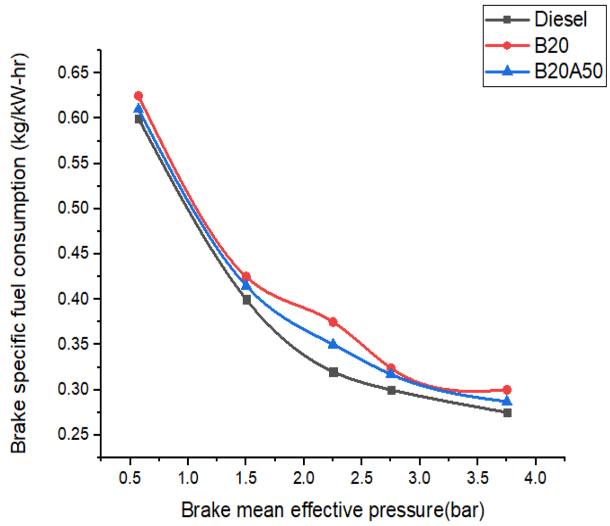

Figure7: Variation of Brake Specific Fuel Consumption.

6.3.2 Brake Thermal Efficiency

"The influence of Al_2O_3 nanoparticles in BTE with respect to BMEP of the test engine has been provided in figure 8. It was observed that the Alumina nano particle added PME gave the higher BTE compared to PME bio- diesel due to the combustion improvement. Enhanced with high oxygen, easy evaporation characteristics, micro explosion phenomena and higher surface to volume ratio characteristics of nano particles leads to increased BTE [21, 22]. The BTE of B20A50 was around 28% which was higher than that of B20 PME fuel having 25.3%. The BTE of B20A50fuel blend was increased 4.01% compared to 40 PME. The brake thermal efficiency tends to increase with increase in engine brake mean effective pressure. The improvement in BTE at higher brake mean effective pressure was due to the attainment of higher brake power for corresponding increase in fuel rate. It was seen that all Alumina Nano emulsions have shown higher brake thermal efficiency compared to Pongamia biodiesel at all engine BMEP conditions. This may be attributed to the micro explosion phenomena of water in the fuel and catalytic effect of metal oxides which contributes in higher brake thermal efficiency in [23,24]. The water particle in the nano emulsion fuel leads to fast evaporation and better mixing of fuel particles with air".

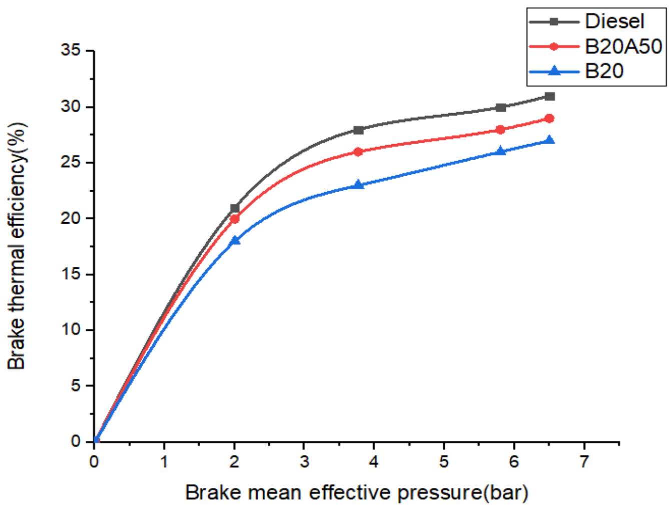

Figure 8: Variation in Brake Thermal Efficiency.

7. CONCLUSIONS AND FUTURE WORK

Biodiesel has higher fuel consumption, because of its inferior heating value. With the addition of aluminium oxide nano particles, there is a considerable reduction in fuel consumption compared to biodiesel operation. A minor increment in BTE was observed with the addition of ANP to biodiesel blend.

Alumina nano particle reduced HC and CO emissions up to 26.04% and 48% compared with a biodiesel blend, because Alumina acts as an oxygen buffer catalyst and donates surface lattice oxygen for the oxidation of HC and CO. NO_x emissions increase with the use of ANP and biodiesel blend compared to the diesel fuel.

And it is noted that BSNOx emission for the Pongamia fuel was 35% higher than conventional diesel fuel at 100% engine load because of the intrinsic oxygen content in the Pongamia fuel along with higher peak combustion temperature during Pongamia fuel operation as an effect.

The peak pressure increases with the addition of Alumina. The addition of Alumina reduces the ignition delay period. The heat release rate also increases with the addition of Alumina nano particle. The addition of Alumina accelerates the hydrocarbon combustion and is the reason for the higher heat release rate when compared with neat diesel and biodiesel blend. The maximum cylinder pressure of B20A50, B20 were 1.16%, 0.346% more (on average 0.27%) than the Diesel respectively as the biodiesel possesses lower peak cylinder pressure because of the long ignition delay.

The BTE of B20A50 was around 28% which was higher than that of B20 PME fuel having 25.3%. The BTE of B20A50 fuel blend was increased 4.01% compared to 40 PME due to the attainment of higher brake power for corresponding increase in fuel rate.

The B20 and B20A50 fuels displayed peak heat release rates of 94.2 kJ/°CA and 92.3 kJ/°CA, at 369°CA and 372°CA ATDC respectively than the that of the PBD fuel as the condition causes rapid vaporization of the PBD, thereby contributing to pre-mixed combustion.

7.1 Future Prospects that can be done

The efforts to be made to investigate the effect of thermal properties of nano fuel additives on combustion.

- “Further investigations are needed to study the effects of same nano fuel additives in different biodiesel to select appropriate biodiesel-nano particles combination.
- Further researches are needed to investigate the effect of nano additives on the exhaust after treatment devices.
- The optimum combination of concentration and size of nano particles are needed to study in future.
- CFD of injector spray of fuel containing nano particles can be further research of investigation”.

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